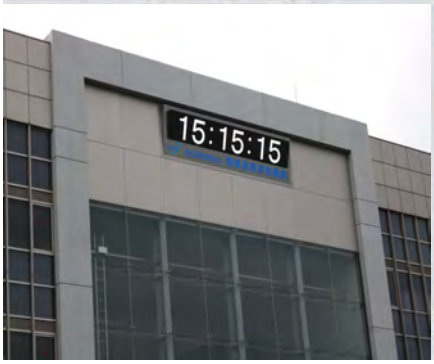
Space-Time Standards Laboratory

Japan Standard Time Group

National Institute of Information and Communications Technology

Japan Standard Time Group—Generation, Comparison, and Dissemination of Japan Standard Time and Frequency Standards



NICT

The National Institute of Information and Communications Technology (NICT) is responsible for the important tasks of Generation, Comparison, and Dissemination of Japan Standard Time and Frequency Standards, which have a direct impact on people's lives. In this brochure, we first explain how International Atomic Time and Coordinated Universal Time are calculated. We then look at how the standard time all over the world, including Japan Standard Time, is generated based on them. Finally, we introduce three major functions of the Japan Standard Time Group: Generation, Comparison, and Dissemination of Japan Standard Time.

What is the Time?

■ Definition of a Second

Definition of a second: The duration of the unit "second" was first defined according to ephemeris time, which is tied to the rotation and orbital motion of the Earth. Since 1967, however, the second has been defined in terms of the frequency of atomic radiation under the International System of Units (SI). The second is defined in the SI as "the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom."

■ International Atomic Time (TAI)

The time scale created by atomic clocks is referred to as atomic time.

The International Atomic Time (TAI) was synchronized with (Universal Time 2) (UT2) at 0:00 on January 1, 1958, and the two have since drifted apart. TAI is decided by calculating a weighted average time of atomic clocks around the world.

■ Coordinated Universal Time and Leap-Second Adjustment

Our daily lives are governed by the apparent motion of the Sun. Since the time scale used in measuring time is atomic time, there is a need for an atomic time that is close to Universal Time (UT).

This atomic time is called Coordinated Universal Time (UTC).

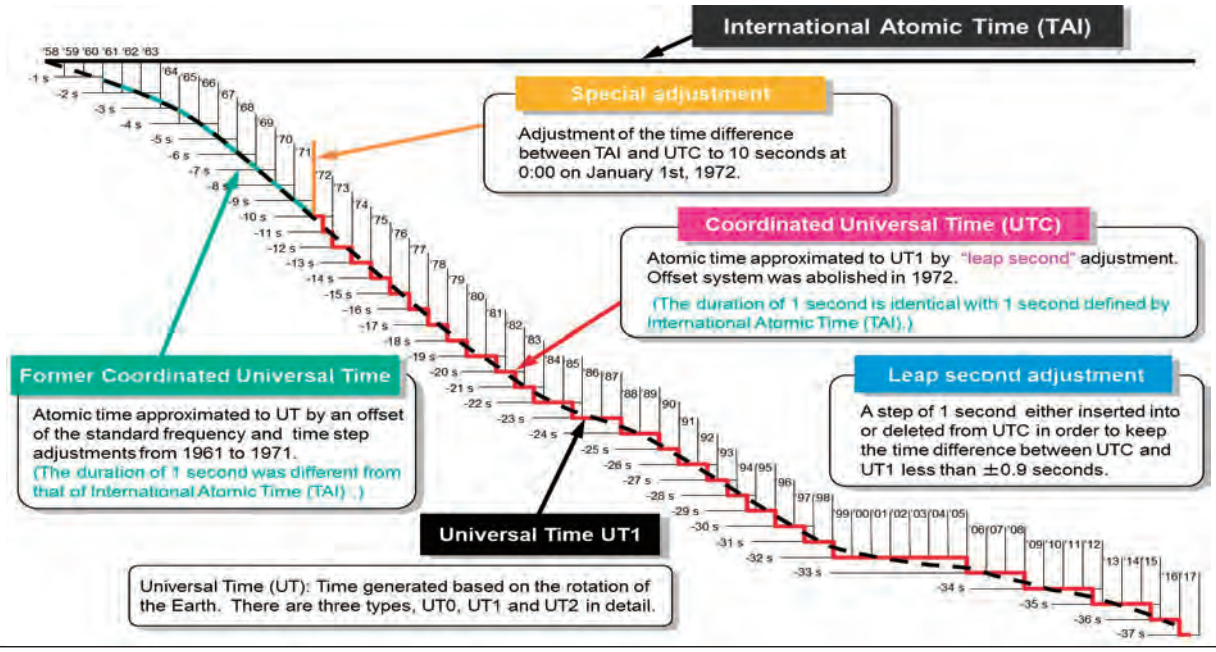
As the angular velocity of the Earth is affected by natural phenomena such as tidal friction, the mantle, and the atmosphere, a time difference between UT and UTC is fluctuated. Therefore, to keep the time difference between UTC and UT within 0.9 seconds, "one second" is either inserted into or deleted from UTC.

This one second is referred to as a "leap second."

Leap-second adjustment was introduced after a special adjustment was carried out in 1972. Leap-second adjustments have been performed 27 times from 1972 to January 2017. All adjustments so far have involved inserting one second to UTC, and UTC is now 37 seconds behind TAI.

■ Japan Standard Time (JST)

Japan Standard Time (JST) is defined to set 9 hours forward of UTC (NICT); the meridian line of Japan is at 135 degrees eastern longitude.



Generation of JST

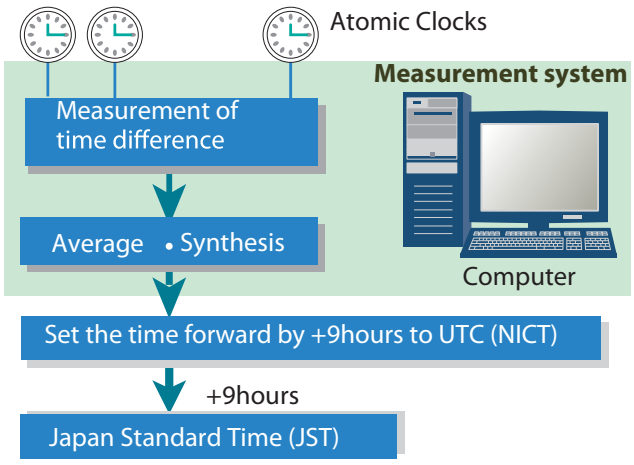
■ Atomic Clock

JST is obtained using a maximum of 18 cesium atomic clocks and four hydrogen masers in accordance with the definition of the unit of the second as mentioned above.

Cesium atomic clocks are good for long-term (longer than 5 days) stability and hydrogen masers are good for short-term (shorter than 5 days) stability.

The frequency (i.e., the number of oscillations per second) of each atomic clock is easily affected by environmental conditions such as temperature, humidity, and the geo-magnetic

To stabilize the frequency, atomic clocks are mounted in temperature-and humidity-controlled "Clock Rooms" with electromagnetic shielding. Furthermore, each atomic clock is connected to an uninterruptible power supply unit in case there is a power outage.



TAI (International Atomic Time)

determined by the International Bureau of Weights and Measures (BIPM)

UTC (Coordinated Universal Time)

determined by the BIPM

UTC (NICT)

determined by the NICT

JST (Japan Standard Time)

set 9 hours forward to UTC (NICT)

(Left) Hydrogen maser clock (Right) Cesium atomic clock

■ Generation of JST

Mutual time differences of cesium atomic clocks and hydrogen masers mounted in four Clock Rooms are regularly measured every second by a specific measurement system. UTC (NICT) is UTC generated by the National Institute of Information and Communications Technology (NICT) from averaging and synthesizing data obtained from atomic clocks once an hour. This series of procedures for generating JST is fully and automatically performed by computers. Three redundant units (the main unit and backups) work in parallel, ensuring the continual generation of JST in the event of equipment failure.

■ Establishment of Distributed Structure

Until recently the generation of JST was carried out only at the NICT headquarters in Koganei City, Tokyo. However, at the time of emergency, such as a serious natural disaster, in Tokyo, the operation of JST in headquarters might be stopped due to infrastructure damage.

To increase reliability, therefore, we are promoting research and development for decentralization of the JST facilities. As the first step, JST sub-station was established in Kobe City, Hyogo on June 10, 2018.

The equipment for JST sub-station, including cesium atomic clocks and high precision satellite time and frequency transfer systems, were installed there. The two accurate time scales generated in Tokyo and Kobe are always compared. At the emergency of Tokyo, Kobe Sub-station can function as the main JST station instead of the NICT headquarters.

Development of technology to consolidate multiple time scales will further bring more accuracy of JST by using atomic clocks of distant stations, including the LF standard time and frequency transmission stations.

Comparisons with JST

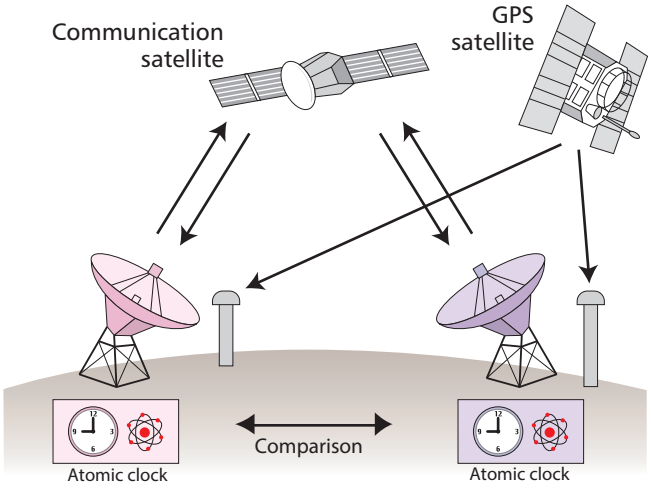
Comparison of UTC and JST

The NICT manages UTC (NICT) to approximate UTC and decrease the time difference between UTC and UTC (NICT) within ±10 nanoseconds (1 nanosecond = 1/1,000,000,000 seconds). To make this adjustment, highly precise international time comparison methods using Global Navigation Satellite Systems (GNSS) such as Global Positioning System (GPS) and communication satellites are implemented.

Standards institutes around the world manage their standard times, and each institute reports time information for each atomic clock in terms of time differences to Bureau International des Pods et Mesures (International Bureau of Weights and Measures) [BIPM]. BIPM decides the TAI and UTC on the basis of the data collected from each country.

International Comparison

The NICT adopts two methods in making precise international time comparisons.



(1) Time comparison using GNSS:

It is possible to obtain the difference between time information transmitted by navigation satellites such as GPS and UTC generated by each institute having atomic clocks.

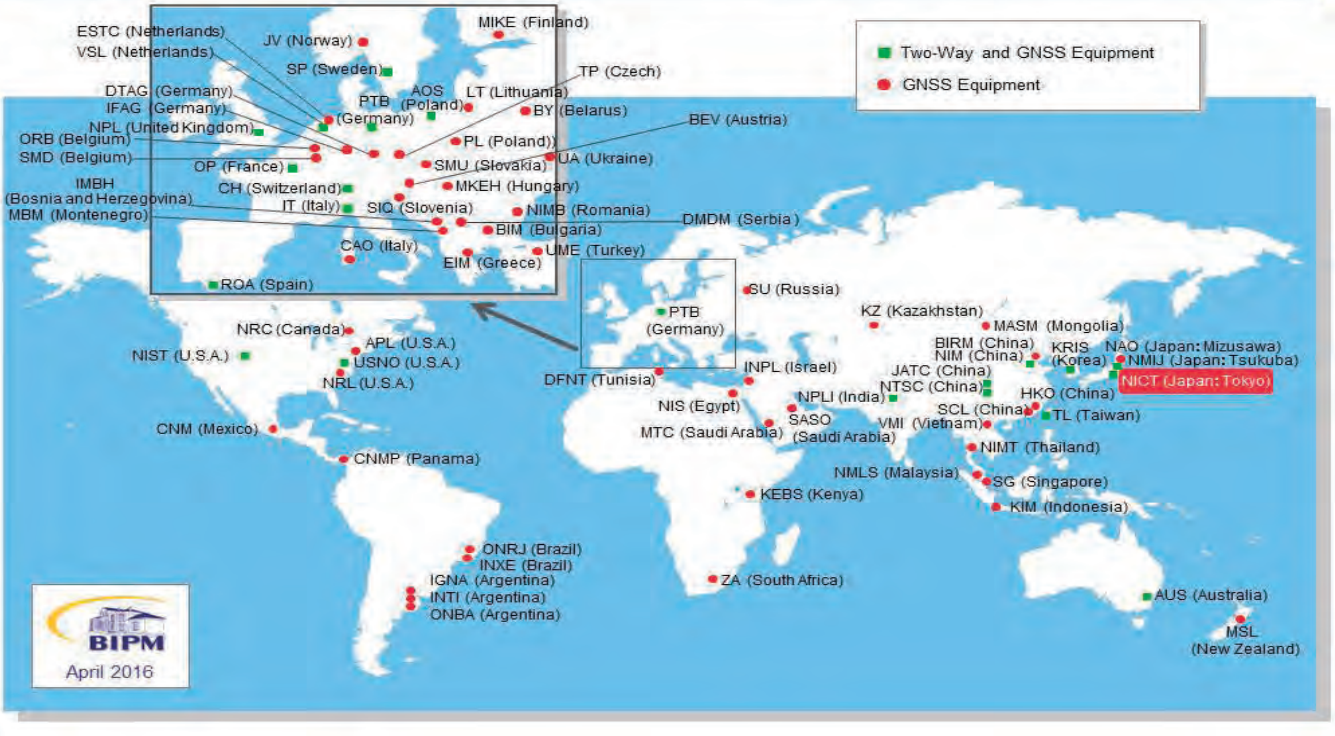
UTC (NICT) and UTC obtained by each institute are compared using time information of satellites as an intermediary in the calculations. The times reported by two standard stations are compared with precision of about one-hundred millionths of a second to even ten billionths of a second.

(2) Time comparison using communication satellites:

Two stations simultaneously transmit time information using communication satellites, and the time difference is calculated. The precision of this time comparison is about one billionth of a second to ten billionths of a second.

Nowadays, many highly precise time comparisons are made using the two methods.

Geographical distribution of the laboratories that contribute to TAI and time transfer equipment (April 2016)



Dissemination of JST

Low-Frequency Standard Time and Frequency Transmission Stations

The standard time and frequency transmission (JJY*) is a radio wave used to supply standard frequencies and JST throughout Japan. Radio-controlled watches and clocks are now widely used by the general public and they synchronize with JST by receiving this standard radio wave.

The first operational station, namely the Ohtakadoya-yama Low-frequency (LF) Standard Time and Frequency Transmission Station, started transmitting a standard wave (40 kHz) in June 1999. To provide a back-up and strengthen the signal in southwestern Japan, the Hagane-yama LF Standard Time and Frequency Transmission Station commenced transmission of a standard wave (60 kHz) in October 2001.

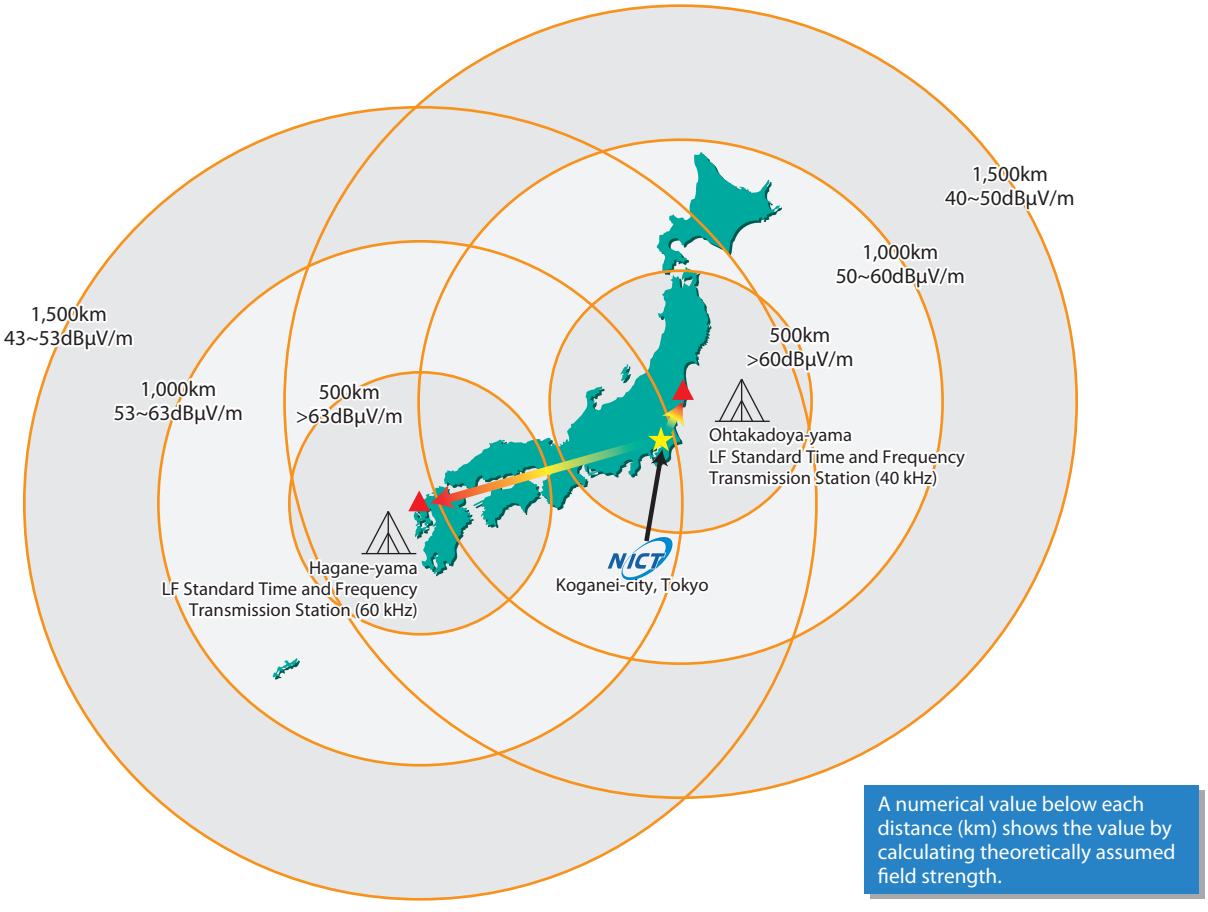
An LF standard time and frequency transmission signal includes a time code giving the minute, hour, day of year (counted from January 1), year (last two digits of the dominical year), and day of week. This time code is used for reception devices such as radio-controlled clocks with automatic time correction functions.

The time code signal is expected to be used in a wide range of applications, such as clocks in home electronic appliances, cameras, and automobiles, and the built-in clocks of measuring instruments and seismometers. The standard frequency supplied by the LF standard time and frequency transmission signal is also expected to serve as a precise frequency standard for a variety of applications, such as measuring instruments, communication devices, master standard devices of electronic manufacturers, and standard oscillators used in ground-based digital broadcasting.

Although the LF standard time and frequency transmission signal has ordinarily been transmitted for 24 hours a day, it may temporarily be suspended because of maintenance checkups of devices and antennas, or in the event of possible lightning.

The status of transmission or suspension is announced on the website. http://jjy.jp/

*JJY is the call sign of the radio station and is a registered trademark (T4355749) of the NICT.



A numerical value below each distance (km) shows the value by calculating theoretically assumed field strength.

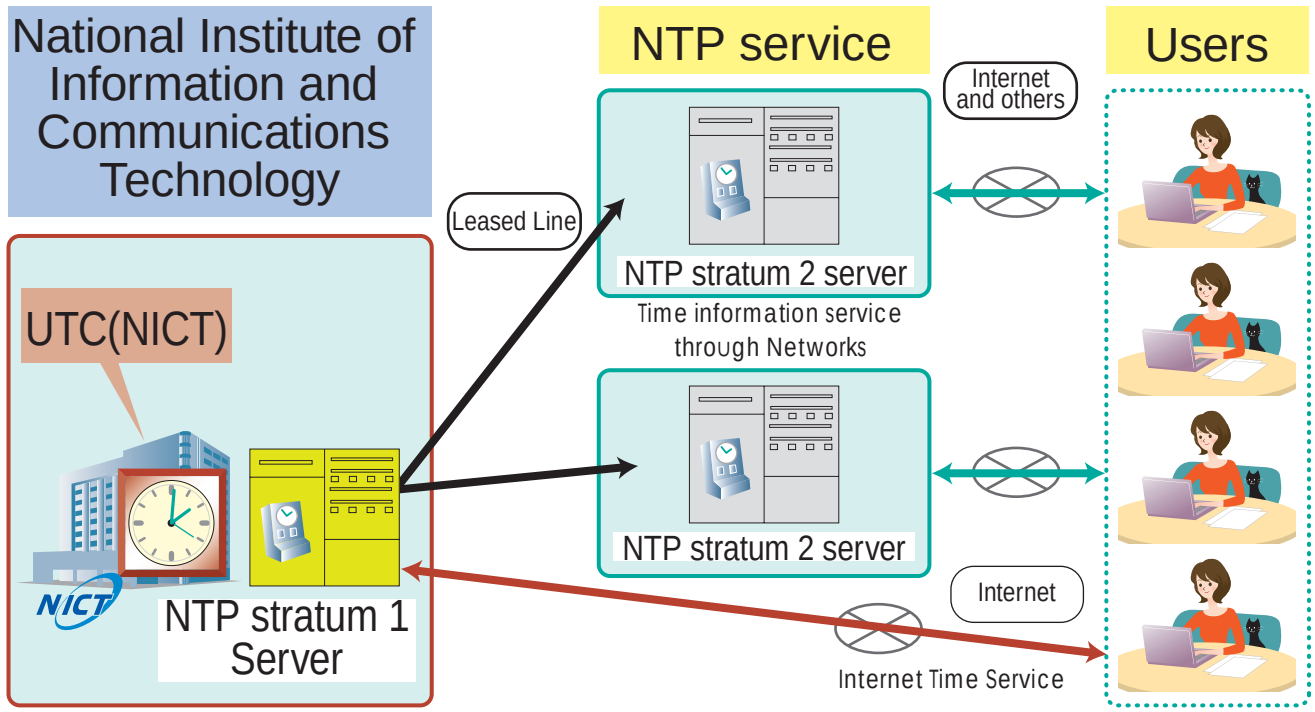
Internet Time Service

In today's computerized society, most computers transfer many data via networks. During these processes, the file update time is usually defined by the built-in clocks of individual computers. These built-in clocks of personal computers, however, are not highly precise, and so, without regular periodic time synchronization, inconsistencies tend to occur in file information. Therefore, the NTP (Network Time Protocol) is widely used to synchronize the times of networked computers.

The Japan Standard Time Group (JSTG) offers "Time Information Service by Networks" to the time-dissemination enterprises authorized as Time Businesses, and Internet-related corporations.

Through this service, stable time information is provided by directly connecting users' servers with an NTP server linked up with JST. The JSTG also offers an "Internet Time Service" to general users so that they too are able to use an NTP server (ntp.nict.jp) that links up with JST.

Architecture of Time Information Service through Internet



Telephone Time Service

Conventionally, high-frequency (HF) standard transmissions were widely used to synchronize clocks for business applications, such as the master clocks of broadcasting stations. On August 1, 1995, a new system came into operation, supplying a high-precision time signal electronically via analog telephone lines (telephone JJY). A personal computer, modem, and commercial communications software are all that is required for users to acquire time information with precise adjustment for delays in the telephone line.

Dedicated receivers for commercial use perform time synchronization using JST with precision of less than one millisecond, equivalent to the precision of conventional commercial HF receivers, by measuring and correcting the delay in communication lines using the bi-directional telephone connection. Dedicated receivers are widely used in commercial applications, especially at broadcasting stations.

For more information, please visit http://jjy.jp/.

Hikari Denwa Time Service

A new system for supplying JST via NTT Hikari Denwa line networks (Hikari telephone JJY) has been constructed and started an experimental operation in May 2016. The NICT aims to shift the present telephone JJY to this new system in the future.

Further information will be updated on JSTG website accordingly.

■Calibration of the Frequency Standard

As part of its duty to provide a standard frequency, the JSTG performs a frequency standard calibration. The deviation of frequency standards from the national frequency standards is measured.

There are four types of calibration of the frequency standard:

1) Calibration in compliance with Japanese Radio Law

2) Calibration in compliance with Japanese Measurement Law (jcss* calibration)

3) Calibration in compliance with CIPM-MRA** (ASNITE*** calibration)

4) Commissioned calibration

* jcss : Japan Calibration Service System using National Standard

**CIPM : International Committee for Weights and Measures

MRA : Mutual Recognition Arrangement

***ASNITE : Accreditation System of National Institute of Technology and Evaluation

In the case of calibrations (2)–(4), clients may select either

(a) calibration of the frequency standard (carried into the NICT and carried out with the NICT facilities, or

(b) remote calibration (implemented by time comparison using GPS satellites as an intermediary).

In the case of calibration (2), the NICT is a designated calibration organization authorized by the Minister of Economy, Trade, and Industry, and it issues a calibration certificate to a client to prove as an accreditation to operate.

In the case of calibration (3), the calibration system is certified in accordance with the international standard ISO/IEC 17025:2005 (JIS Q 17025:2005). The NICT is permitted to issue a calibration certificate for global Mutual Recognition Arrangement (MRA.) (Disciplined oscillators that transmit a frequency by synchronizing with external signals are not covered.)

In the case of calibration (4), in addition to commissioned frequency calibration, the short-term stability is measured.

Details are given at http://cal.nict.go.jp (Japanese version only).

	Radio Law	Measurement Law	CIPM-MRA (ASNITE)	Commissioned
Calibration of frequency standard	Carried-in	Carried-in Remote	Carried-in Remote	Carried-in Remote
Measurement of short-term stability	N/A	N/A	N/A	Carried-in

"Carried-in" calibration is directly available
Courier service is available

"Remote" calibration is available

"N/A (Not Available)"

Frequency Standard Calibration System

An Information Technology Society

■Electronic Time Authentication

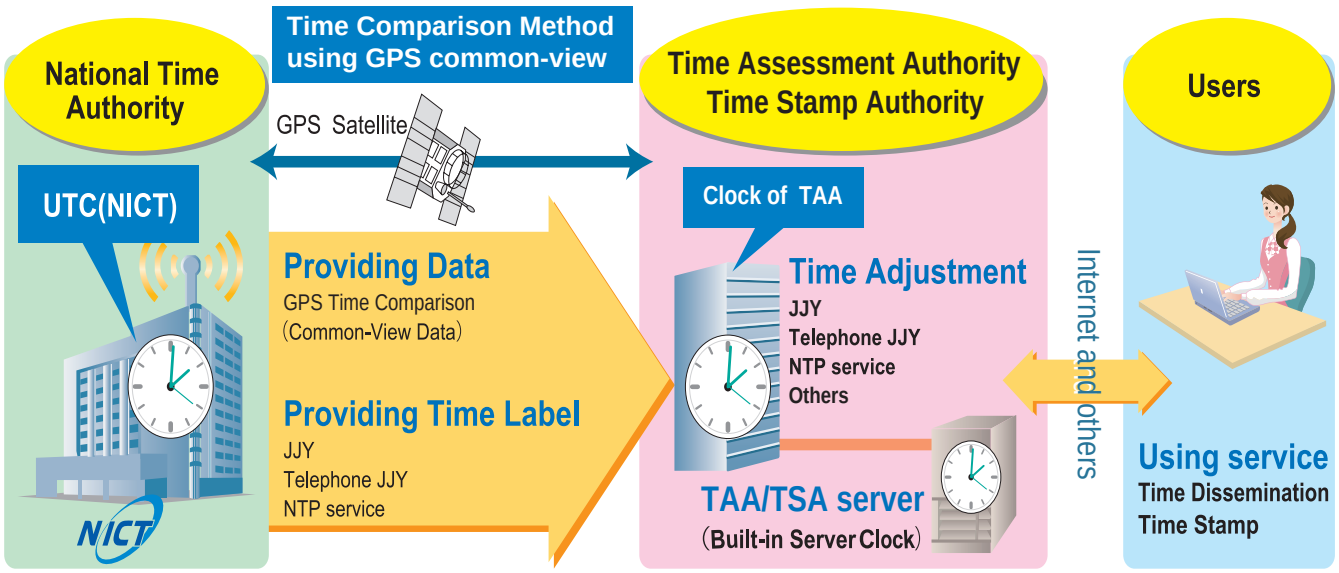
The concept of incorporating precise time into information technology (IT) is referred to as new words "time business," which mainly consists of "time dissemination" and "time authentication" business. The IT community has been encouraged to adopt precise time; e.g., as a timestamp. A Japanese law on e-documents, which came into effect in April 2005, requires time stamps to be put on electronic documents to certify that they have not been altered, and it is inevitable for precise time information to be used for the time stamps.

The JSTG began disseminating JST, which is traceable to UTC, to the general public in February 2005. This has made it possible to use precisely and socially authorized electronic time information.

A system, in practice, is constructed as shown in the figure below. The NICT, as the National Time Authority (NTA), provides JST to the Time Assessment Authority (TAA) by publishing the measurement data on the Internet using a GPS common-view method, and then provides users the precise time, which is traceable to JST via the TAA and the Time Stamp Authority (TSA).

Since the time comparison method using the GPS common-view is able to measure 1 second with accuracy of about 10 nanoseconds but unable to measure the time label itself, the Telephone JJY, NTP, and JJY operated by the JSTG are used to adjust time.

In addition, the JSTG has promoted the use of traceability chains of UTC (NICT) to the TSA and the structure of the time dissemination and the audit carried out by the TAA. Technical requirements for the TAA have already been established in Japanese Industrial Standards (JIS X 5094) and also established in ISO/IEC 18014-4 by the International Organization for Standardization in 2015.



National Institute of Information and Communications Technology
Applied Electromagnetic Research Institute,Space-Time Standards Laboratory,Japan Standard Time Group
4-2-1 Nukui-Kitamachi, Koganei, Tokyo 184-8795 Japan
Tel: +81-42-327-6985 Fax: +81-42-327-6689 URL: http://jjy.nict.go.jp E-mail: horonet@ml.nict.go.jp

The 1st edition: Oct. 2004
Revised: Nov. 2018